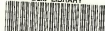


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HABITAT AND NEST SITE SELECTION BY BURROWING OWLS

IN THE SAGEBRUSH STEPPE OF IDAHO

by

TERRELL RICH

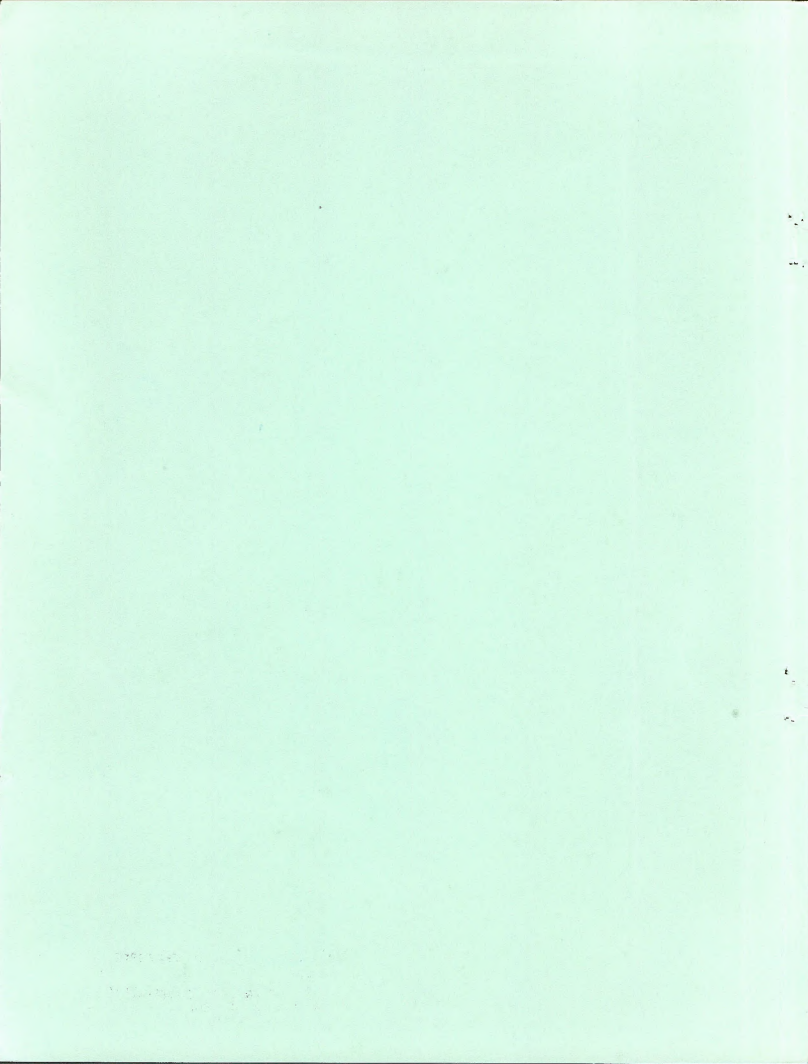


Technical Bulletin 85-3

June 1985

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Habitat and Nest Site Selection by Burrowing Owls
in the Sagebrush Steppe of Idaho

by

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Idaho BLM
Technical Bulletin 85-3
June 1985

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The burrowing owl is classified as a "Sensitive Species" in Idaho and, as such, has been a high priority species in BLM's Wildlife Habitat Management Program. J. B. Silva initiated burrowing owl studies within the Shoshone District in 1976. Since 1979, Terry Rich has intensified these studies. Mr. Rich has reported on progress with the studies at Idaho BLM Wildlife Workshops; at the 1983 Annual Meeting of the Cooper Ornithological Society in Albuquerque, New Mexico; and the 1984 Idaho Chapter Meeting of the Wildlife Society in Boise. He has also published results in the Wildlife Society Bulletin 12:178-180, 1984, under the title "Monitoring burrowing owl populations: implications of burrow re-use"; in Idaho Wildlife 4(4):18-20, 1984, under the title "Burrowing Owls"; and in The Murrelet 64:25-26, 1983, with B. Trentlage under the title "Caching of long-horned beetles (Cerambycidae: Prionus integer) by the burrowing owl."

Mr. Rich has transferred to the Dickinson District Office in North Dakota. His present address is USDI Bureau of Land Management, P.O. Box 1229, Dickinson, ND 58602.

HABITAT AND NEST SITE SELECTION BY BURROWING OWLS
IN THE SAGEBRUSH STEPPE OF IDAHO

TERRELL RICH

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Abstract. The local topography and vegetation around 80 occupied burrowing owl (Athene cunicularia) nest sites in the sagebrush steppe of southcentral Idaho were quantified. Several additional topographical variables within a 1-km radius and habitat variables within a 693-m radius of these sites were then compared with data for an equal number of randomly chosen sites. Owls used burrows provided by badgers (Taxidea taxus) in open soil and by marmots (Marmota flaviventris) in small lava outcrops; the latter were chosen more often. Cover within a 50-m radius of burrows was mainly bare earth, cheatgrass (Bromus tectorum), rock, and annual forbs. Owls avoided dense vegetation. In comparison to randomly chosen sites, occupied sites had a greater cover of cheatgrass, had a greater habitat diversity, were lower in elevation, and were more frequently placed on southerly aspects. Agricultural land occurred on 30 occupied sites and 33 randomly chosen sites but averaged less acreage on occupied sites. Sagebrush (Artemisia

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tridentata) occurred on 48 occupied sites and 32 randomly chosen sites and also averaged less acreage on occupied sites. Surface water was present on 14 occupied sites but only 2 randomly chosen sites. Burrow security and prey availability, especially the proximity to populations of Microtus montanus on agricultural land, may explain some of the habitat selection observed.

Burrowing owls (Athene cunicularia) breed in a variety of western habitats (Bent 1938) including deserts (Best 1969, Martin 1973), plains (Grant 1965, Butts 1973, Howie 1980), and shrubsteppe (Gleason 1978, Green 1983). Good breeding habitat is characterized by openness, short vegetation, and availability of abandoned mammal burrows (Bent 1938, Zarn 1974). Recent population declines (Zarn 1974, Collins 1979) have been attributed to control of burrowing mammals (Butts 1973) and loss of habitat to cultivation (Howie 1980). Because of the population status of the species, land management and wildlife agencies have placed a special emphasis on managing burrowing owl habitat in Idaho to maintain or improve the population. However, no detailed studies of nest site and habitat selection have been made in the shrubsteppe of southern Idaho. Determination of these requirements is needed in order to aid decisions involving land use and habitat manipulation.

This study was designed to quantify the habitat and nest site preferences of burrowing owls in southern Idaho. One objective was to determine if the habitat occupied by owls differed from that available to them. To do this I compared topographic and vegetative features of occupied nest sites with those from randomly chosen sites. This approach to

understanding nest site and habitat selection has been successfully used on a wide variety of avian species (e. g., Burger and Shisler 1978, MacKenzie and Sealy 1981, Titus and Mosher 1981, Redmond et al. 1982, Clark et al. 1983). In particular, I applied stepwise discriminant function analysis to identify important variables that differ between occupied and randomly chosen sites. Discriminant function analysis also allows one to predict from future data sets, in this case topographic and vegetative variables, whether particular sites are likely to be occupied by burrowing owls. This capability has practical management value and was tested using data from a second set of occupied sites.

Because burrowing owls do not regularly dig their own burrows (Zarn 1974), a study of their nest site selection analyzes the habitat selection of burrowing mammals to some degree. Alternatively, I could have compared occupied nest sites with unoccupied, but suitable, burrows. However, one cannot tell whether burrows unoccupied in one year have been used in the past or will be used in the future (Rich 1984). It would also violate an important assumption of discriminant function analysis (Williams 1981).

Furthermore, many suitable natural rock cavities and burrows would not be considered because they are too numerous to document. For example, in similar habitat of an adjacent area in southcentral Idaho, 526 badger (Taxidea taxus) burrows that appeared suitable for habitation by owls were surveyed in 1979 and only 6 were occupied (T. and E. Craig, pers. comm.). In southwestern Idaho, badgers dig up to 39 burrows per hectare (Messick and Hornocker 1981). Green (1983) concluded that vegetative characteristics, not burrow availability, determined suitable breeding habitat because occupied habitat actually had fewer available burrows than unoccupied habitat. Thus, I believe the owls were not significantly limited by

availability of burrows in my area and that the approach outlined above is an effective one.

I also analyzed diet to determine if it was significantly correlated with habitat selection. I reasoned that since prey density and availability vary greatly among the available habitats, this might be a major proximate factor influencing nest site and habitat selection.

I thank B. Trentlage for help with field work and E. Cowley for allowing time for this study. J. Carter, R. Johnstone, F. Ireton, L. Mangan, S. Langenstein, B. Parmenter, and C. Taplin helped by reporting burrowing owls and nest sites. M. Moritsch kindly provided vegetative data for sites in the Snake River Birds of Prey Natural Area. The manuscript was improved by the comments of D. Martin, F. Jaksic, C. Marti, L. Mangan, C. Collins, and L. Blus. I also thank M. Padgett for handling the word processing of this paper.

STUDY AREA

The study area, located on the Snake River Plain in southcentral Idaho (Fig. 1), has flat to rolling topography and elevations between 900 m and 1500 m. Much of the study area has volcanic features including unvegetated and partially vegetated lava flows, lava outcrops, and buttes. Annual precipitation is 25 cm with most falling between December and June. Mean annual temperature is 9° C with a monthly mean of 23° C in July and -4° C in January.

The native vegetation is mainly sagebrush (Artemisia tridentata tridentata, A. t. wyomingensis, and A. tripartita), rabbitbrush (Chrysothamnus viscidiflorus and C. nauseosus) and the grasses Stipa

thurberiana, Agropyron spicatum, A. smithii, Poa sandbergii, Sitanion hystrix, and Elymus cinereus. However, large areas have been converted to irrigated agriculture (Fig. 1) so that water is available in many places where it was not historically. Recurrent wildfires have allowed much of the rest of the area to be dominated by cheatgrass (Bromus tectorum), an exotic annual. Most of the range habitat is grazed by sheep or cattle.

METHODS

Between 1 March and 1 August 1981, I spent 2-3 days per week in the field searching for nest sites and making measurements on sites found by me and my co-workers. Eighty occupied sites located during this period were used in this analysis. Other nest sites were located between 1976 and 1981 and in 1983. None of these sites were used in the present analysis. However, their locations are also shown in Fig. 1 and this total known distribution of occupied sites was used to define the breeding range of the burrowing owl in the study area for random site selection.

Between 1 May and 1 August 1982, I spent 1-2 days per week in the field and located 47 occupied sites that were either not occupied or not detected in 1981. Only elevation and data from aerial photographs as described below were recorded for these sites. These data were used primarily to test the predictability of the classification functions derived from discriminant function analysis of the original 80 occupied and 80 randomly chosen sites.

A site was considered occupied if young were observed or at least one owl, fresh castings, and a debris ring were present. Where alternate burrows occurred, the nesting burrow was identified by a larger debris ring.

For the 80 occupied burrows located in 1981 the following information

was obtained: Presence of rock outcrops within a 1-km radius, type of burrow, compass orientation of burrow opening, slope and aspect of the ground within a 50-m radius, height of outcrop (if present) above the burrow, maximum right-angle dimensions of the outcrop, estimated percent ground cover within 2 m and 50 m of the burrow, and number of alternate burrows.

For comparison I selected 80 sites at random from within the known range of the burrowing owl in the study area. Random numbers were used to select a township, range, section, and point within the section for each site. A site thus selected was acceptable unless it fell on a road, water surface, agricultural field, or was within 100 m of an occupied human dwelling or livestock facility. In the seven cases where unacceptable sites were selected, new numbers were used to establish acceptable sites. Each occupied and randomly chosen site was plotted on a 7' topographic map and the following information obtained: elevation of site, maximum and minimum elevation within 1 km, relief, slope, and slope aspect of the land within a 1-km radius.

Finally, the same sites were plotted on aerial photographs (1:24,000) to determine cover of five different habitat types: cheatgrass, sagebrush, agriculture, water, and lava. Agricultural crops consisted mostly of hay. I recorded the area in each habitat type within six concentric zones centered on the site. Beginning with the innermost, the areas of these zones were: 12.56 ha each for zones 1A, 1B, and 1C and 37.68 ha each for zones 2, 3, and 4 for a total of 150.72 ha per site. The radius of zone 1A was 200 m and the outer radius of zone 4 was 693 m. This area was larger than the 50- and 80-ha hunting areas of two males determined by telemetry studies (T. and E. Craig, pers. comm.) and far larger than defended

territory size (Thomsen 1971). Distance to water, including irrigated cropland, was the final variable measured from the photographs.

I collected regurgitated pellets between 15 July and 31 July from 52 of the nest sites located in 1981. A random sample of 10 pellets from each site was analyzed for all identifiable prey. A subset of these data, which consisted of more commonly occurring prey items, was then correlated with the area in each of the habitat types.

Univariate statistical analysis follows Zar (1974) whereas ANOVA and discriminant function analysis were performed with programs in the BMDP series (Dixon 1981). In the text all values following means are standard deviations. Data screening revealed that distributions of several variables were positively skewed. These variables were log-transformed before analysis and are so noted in the text and tables. Also, where I used the parametric one-way ANOVA to test for habitat cover differences among zones, I also analyzed the data with the nonparametric Kruskal-Wallis test (Zar 1974). Interpretations of results of the latter tests were identical with those obtained from the parametric tests. Therefore, only results of the parametric tests are reported.

RESULTS

Burrowing owls arrived on the study area in early April but nest site conspicuousness peaked in July when most young were fledging yet remained close to the burrow. Since 1976 young have been observed near natal burrows as early as 10 June and as late as 17 September. Between the summers of 1976 and 1983, 242 occupied burrows were located (Fig. 1).

Burrow Characteristics

Outcrop and mound sites.--I classified occupied burrows located in rock outcrops as outcrop sites and those in mounds of soil as mound sites. Outcrop sites were often abandoned burrows of yellow-bellied marmots (Marmota flaviventris) but several consisted of natural rock cavities. Badgers excavated most mound sites but a few burrows were probably dug by coyotes (Canis latrans). In 1981, 28 outcrop sites and 52 mound sites were located. Alternate burrows were present at 3 of 28 (11%) outcrop sites and at 19 of 52 (37%) mound sites.

The number of outcrops available within 1 km of each occupied site was ranked as high, medium, or low. Within each rank the number of outcrop and mound sites respectively were: high, 17 and 12; medium, 10 and 30; low, 1 and 10, respectively. The type of nest site was not independent of the availability of outcrops ($\chi^2 = 12.12$, $P < 0.005$), i.e., burrowing owls used outcrop sites more than expected on the basis of availability. They also preferred smaller outcrops. Mean dimensions of the 28 occupied outcrops were: width 10 ± 8 m and length 16 ± 13 m (excluding four outcrops that were more than 50 m long). Many larger outcrops were available - some extended for several km.

Burrow orientation, slope aspect, and slope.--Mean angles and angular dispersion (Zar 1974) indicated random orientation of burrows on the 80 occupied sites. However, there was a highly significant correlation between orientation and slope aspect of the 42 burrows placed on slopes ($r = 0.89$, $P < 0.001$), i.e., most burrows were simply dug more or less into the slope.

The owls preferred flat sites as 79% of the burrows were located on slopes of 10° or less (Fig. 2). Burrows were not randomly placed with

respect to slope ($\chi^2 = 65.89$, $p < 0.001$) with an excess of sites on flat terrain. At outcrop sites, openness was reflected in the minimal height (42 ± 24 cm) of the rock face under which the burrows were located. Thus, owls selected sites with low profiles typically near a perch with a 360° view.

Local Vegetation

Cover within 2 m of the burrow was dominated by bare ground, cheatgrass, rock, and burr buttercup (Ceratocephalus testiculatus). Other plant species occurring on a few sites were perfoliate peppergrass (Lepidium perfoliatum) and tumble mustard (Sisymbrium altissimum). Among shrubs, I found sagebrush on only two sites and rabbitbrush on three sites.

Cover within 50 m of the burrow (Table 1) was mainly cheatgrass with substantial portions of bare ground. Both sagebrush and rabbitbrush were found frequently but composed only a small portion of the cover. The four genera that indicate highly disturbed sites - Sisymbrium, Ceratocephalus, Cirsium, and Lepidium - were encountered often but did not dominate the sites.

Occupied Versus Randomly Chosen Sites

General topography and slope aspect.--Among the six topographical variables wherein the 80 occupied and 80 randomly chosen sites were compared only three were significantly different - site elevation and maximum and minimum elevation within 1 km (Table 2). These three variables were significantly intercorrelated. Thus, owls selected sites averaging 47 m lower than what was available. Occupied sites also averaged 319 m nearer

water than did randomly chosen sites although the difference was not significant. The slope aspects of occupied and randomly chosen sites (Fig. 3) were significantly different ($\chi^2 = 17.46$, $0.025 < P < 0.05$). More occupied sites than expected were located on all aspects except flat, north, and northeast. The variance in all variables for randomly chosen sites was slightly greater than for occupied sites (Table 2). Thus, owls selected from a narrower range of topographic features than was available.

Vegetation.---I first examined how vegetative cover changed as the estimate of home range was increased (Fig. 4). For three habitat types (excluding water and lava that had small sample sizes) the area of cover did not differ significantly over all zones for either randomly chosen or occupied sites (one-way ANOVA, all $P > 0.20$). In other words, expanding the area around the randomly chosen or occupied site did not significantly alter the probability of encountering a given habitat type. However, there was a sharper decrease in cheatgrass cover between zones 1A and 1B on occupied versus randomly chosen sites. Through zones 2, 3 and 4 trends were similar on both types of sites - a steady decrease in cheatgrass with an increase in sagebrush and agricultural land (Fig. 4).

Second, the mean area of each habitat type differed between occupied and randomly chosen sites. The cover of cheatgrass was significantly greater on occupied sites for zone 1A ($t = 3.75$, $P < 0.001$), zone 1B ($t = 2.13$, $P < 0.05$) and zone 1C ($t = 2.50$, $P < 0.02$) but not significant for zone 2, zone 3, or zone 4 (all $P > 0.10$). For agricultural habitat, cover on occupied sites was significantly less only in zone 1A ($t = 2.86$, $P < 0.05$). For the other zones the difference was not significant (all $P > 0.20$). Sagebrush cover was not significantly different between observed and randomly chosen sites over all zones. The data for lava and water in Figure

4 can be further clarified by reference to Table 3. Sparsely vegetated lava occurred on six randomly chosen sites but no occupied sites. Surface water was found on 2 randomly chosen sites and 14 occupied sites.

The values in Table 3 include means only for those sites with the given habitat. Thus, whereas Figure 4 reveals a greater amount of cheatgrass on an average occupied site, Table 3 indicates that among those sites having some cheatgrass the mean area covered did not differ significantly between randomly chosen and occupied sites. About the same number of occupied and randomly chosen sites had some agricultural land, but the latter averaged over 30 ha greater - significantly more. Sagebrush cover averaged significantly greater on randomly chosen sites yet there were 16 more occupied sites with some sagebrush.

Discriminant Function Analysis.---The usefulness of the topographic and vegetative data in distinguishing randomly chosen from occupied sites was examined through stepwise discriminant analysis. This was done in order to establish predictive models for burrowing owl habitat. In the first analysis all topographic variables were used. Vegetation variables were entered as the area within each zone covered by cheatgrass, agriculture, sagebrush, and water. The cover of lava was omitted to avoid a singularity (Smith 1981). One other variable - an index of diversity (H) (Shannon 1948) - was calculated with the total area in each habitat type for each site. The following variables were significant discriminators between groups: site elevation (EL), distance to water (LOGW - log transformed), diversity (H), and the area in cheatgrass in zone 1A (CLA), zone 1B (CLB), and zone 4 (C4). Because two of the variables not entered - the area in cheatgrass in zone 2 (C2) and zone 3 (C3) - had high F ratios compared with the other variables not entered, I created a new variable (CRest) that was simply the

total area in cheatgrass in zones 2, 3, and 4 and replaced C4 with CRest.

Results of this analysis showed that the amount of cheatgrass in zone 1A was the best discriminating variable (see Table 4, also Fig. 4) with occupied sites having more than randomly chosen sites. Habitat diversity was next best with occupied sites ($\bar{H} = 0.206 \pm 0.166$) being significantly more diverse than randomly chosen sites ($\bar{H} = 0.118 \pm 0.126$) ($t = 3.625$, $P < 0.001$). Elevation was lower, distance to water less (Table 2), and the amount of cheatgrass in zone 1B was greater for occupied sites (Fig. 4). The classification functions (Table 5) succeeded in classifying 77.5% of the sites correctly. About the same number of sites of each type were incorrectly placed.

To test the robustness of these classification functions I entered the data from the 47 occupied sites discovered in 1982. These data did not enter into formulation of the functions but were simply classified by them. These sites were not successfully classified (1982 sites in Table 5) with nearly 60% classified as randomly chosen sites.

I then combined the original 80 occupied sites with the 47 sites found in 1982 to improve the discriminant functions. The new analysis (Table 6) of occupied and randomly chosen sites shows the first three variables entered to be the same as before (Table 4). However, distance to water (LOGW) lost its discriminating value and CRest entered as the last variable selected. The percentage of occupied sites correctly placed (78.7%, Table 7) was almost exactly the same as before (78.8%, Table 5). But the percentage of randomly chosen sites properly identified declined (62.5% versus 76.3%, Table 5).

Occupied sites were more tightly clustered than randomly chosen sites along the discriminant axis (Fig. 5). This supports the data on topography

(Table 2) and slope aspect (Fig. 3) showing that burrowing owls selected from a narrower range of values than was available.

Habitat and Diet

One of the more important factors that might influence burrowing owl habitat selection is prey availability. In cheatgrass, owls apparently concentrated on Perognathus parvus and Nicrophorus spp. (Table 8). The correlation between Perognathus and cheatgrass was the highest in Table 8 suggesting that this prey species is either relatively common or easily captured. The Nicrophorus beetles, although relatively small, were commonly found in pellets and, because of their behavior, may be readily exploited in large numbers.

The only species having a significant positive correlation with agriculture was Microtus montanus (Table 8). This vole is both the largest prey regularly taken and its remains are by far the most commonly encountered items in pellets.

Only Stenopelmatus spp. had a significant positive correlation with the amount of sagebrush habitat. However, this is an important prey animal because it is the largest invertebrate consumed, is easy to capture, and its remains are commonly found in pellets (also see Green 1983).

Among the remaining prey species, Eleodes hispilabris (Tenebrionidae) was not especially associated with any habitat. Although this is a common and relatively large beetle that is easy to capture, its chemical defenses must be effective against owls. Entire pellets are frequently composed of grasshoppers that are apparently available in all habitats in late summer. Prionus spp. was negatively correlated with cheatgrass but not clearly

associated with sagebrush, as expected because of its life history (Rich and Trentlage 1983).

Habitat diversity, a significant discriminator between occupied and randomly chosen sites, was positively correlated with Microtus, Stenopelmatus, and Prionus. Thus, both the most important vertebrate and invertebrate prey increased in the diet of owls in more diverse habitats. Prey diversity was positively correlated with cover of cheatgrass and negatively correlated with agriculture (Table 8). Apparently, owls must take a greater variety of species in the relatively poor cheatgrass habitat as compared to agriculture. There was also a negative correlation between habitat diversity and prey diversity suggesting that in more diverse habitats, owls are able to select from fewer, more profitable, prey species.

DISCUSSION

Burrowing owls preferred small rock outcrops for nest sites (see also Rich 1984) which, although still vulnerable to small predators such as snakes and skunks (Coulombe 1971), might afford protection against badger and canid predation in the burrow. Most of the burrows in the Imperial Valley of California were placed below sandstone and above the softer soil beneath (Coulombe 1971). Other types of nest sites where at least part of the burrow was rigid include road culverts (Wedgewood 1976, pers. obs.), rockpiles, and artificial nest structures (Collins and Landry 1977, Henny and Blus 1981). Badgers not only provide burrows for owls in many areas (Scott 1940, Maser et al. 1971, Butts 1973, Wedgewood 1976, Howie 1980) but also regularly check burrows within their territories (Messick and Hornocker 1981) and dig out nests (Coulombe 1971, Gleason 1978, Green 1983) to prey

upon eggs or young. Domestic dogs caused 20% of the damage to burrows that Thomsen (1971) observed and 10% of the predation found by Green (1983); this suggests that canids such as coyotes might also excavate burrows.

Burrow orientation was found to be governed mainly by the local aspect. Others (Coulombe 1971, Butts 1973, Martin 1973, T. and E. Craig, pers. comm.) have also failed to find any significant orientation preference. Coulombe (1971) found no correlation between orientation and temperature in the depth of five burrows.

Burrowing owls may be one of only a few avian species that benefit from substantially disturbed habitat in the sagebrush steppe. Cover within 50 m of the burrow in this study indicated sites had been disturbed by fire and grazing. But sites were not dominated by plants indicative of the highest degree of disturbance possible for this region (pers. obs.). Thomsen's (1971) study area in California was also dominated by annual grasses and Brassica sp. with only scattered shrubs. In western Minnesota Grant (1965) found burrows in closely-cropped pastures. Martin (1973) worked with owls in New Mexico grasslands dominated by annual grasses with some Atriplex, Chrysothamnus, and Salsola. In Florida owls occupied prairies with sparse, short grasses and scattered, low pines (Stevenson et al. 1980). Howie (1980) reported 60% of the known burrows in Saskatchewan to be in man-produced habitat whereas Wedgewood (1976) observed that prime burrowing owl habitat in that province was produced by overgrazing on poor soils. Grant (1965), Butts (1973), and Martin (1973) also felt that grazing produced favorable habitat in the vicinity of the burrow. I have found occupied and successful burrows in pastures wholly devoid of any vegetation. Coulombe (1971) believed that many miles of otherwise suitable habitat along canals were not occupied in part due to the presence of tall

dense vegetation. Only Scott (1940), working in Iowa, found burrows with tall dense vegetation immediately surrounding the burrow.

Burrowing owls selected from a narrower range of topographical variables than were available although significant selection emerged only for elevation and slope aspect. Outcrop sites, especially, were available on the higher parts of buttes in the study area but, to my knowledge, have never been used. Wedgewood (1976) similarly found that sites in "hill country" were located on flat land between hills.

The distribution of occupied sites on various slope aspects closely paralleled that of randomly chosen sites although there was a significant difference. The present data are insufficient to explain the pattern observed.

Although only 30 occupied sites from 1981 contained agriculture, it is clear that most of the recent known sites have been associated with cultivated lands (Fig. 1). In southwestern Idaho, 41 of 53 nest sites had agricultural land within a 693-m radius (M. Moritsch, pers. comm.). Whereas this was a higher percentage of sites than found in the present study (Table 3), the area in agriculture (77.9 ± 45.3 ha) was almost identical ($t = 0.08$, $P > 0.50$). Gleason (1978) found that owls nesting near irrigated cropland in southern Idaho preyed heavily on Microtus montanus whereas those nesting away from that habitat rarely preyed on this vole. Furthermore, he reported that 14 pairs of owls nesting near agricultural land produced significantly more young per brood than 13 pairs nesting away from agriculture. Diet analysis revealed a positive correlation between the amount of land under cultivation and the number of Microtus in pellets.

Butts (1973) found denser owl populations in areas adjacent to cereal crops and significantly greater densities of rodents and certain arthropods

in croplands as opposed to grass lands. Although cultivated fields supported a large prey biomass in Bechard's (1982) study, dense vegetation made prey unavailable to Swainson's hawk (Buteo swainsoni). The latter species spent more time hunting in habitats where prey density was lower but vegetation was less dense and allowed easier detection and capture. Cultivated fields were hunted only after harvest reduced the vegetation canopy (Bechard 1982). In the present study area, hay is a common crop that is cut two or three times during the summer. The variation in cutting dates yields a mosaic of fields in different stages of growth. Therefore, the rodent populations in these fields are made available throughout the owls' breeding season. Other common crops include wheat and barley that provide good foraging areas early in the season (Bechard 1982) and again following harvest as owls are dispersing.

Sagebrush was an important habitat type on occupied sites. In another part of southern Idaho, 30 of 36 burrows were located within 100 m of sagebrush (T. and E. Craig, pers. comm.). Dense sagebrush stands were not occupied by burrowing owls in my study area even though thousands of hectares of this habitat were available. In fact, invasion of shrubby species may have contributed to population declines in some areas (Best 1969, Howie 1980).

Burrowing owls are known to prey upon a wide variety of animals including aquatic and wetland species such as spadefoot toads, Scaphiopus sp. (Sperry 1941, Gleason 1978), other amphibians (Errington and Bennett 1935, Bond 1942, Schlatter et al. 1980, Jaksic and Marti 1981), and crayfish (Robertson 1929, Hamilton 1941, Marti 1969, 1974). In this study occupied sites were closer to water and more apt to have surface water within the area I examined. Although the hind legs of a frog were found in the mouth

of one burrow near water, no other evidence of the consumption of wetland species was found. The significance of water to burrowing owls remains to be clarified.

For a species that is as opportunistic in its feeding habits as the burrowing owl (Jaksic and Marti 1981, Green 1983) greater habitat diversity should provide a greater variety of potential prey items. Yet diet analysis indicated that diet was less diverse as habitat diversity increased. Owls occupying the simpler cheatgrass habitat had a more diverse diet, i. e., they presumably had to make use of more of what was available and could not afford to concentrate on one prey species. This is consistent with optimal foraging theory (Pyke et al. 1977).

MANAGEMENT IMPLICATIONS

Burrowing owls in the sagebrush steppe make subtle but, I believe, clear habitat selection. Discriminant function analysis may be a useful tool for predicting suitable and unsuitable habitat. Yet the importance of testing the classification functions with new independent data was clearly shown. A refinement in the variables used in the analysis may provide sharper discrimination. In particular, it might be more accurate to use an elliptical home range oriented towards agricultural land rather than a circular one. Soil characteristics may also be important. Whatever the techniques employed, the ecological relationship of burrowing owls and agricultural land, especially, deserves more detailed study. In particular, it is necessary to determine whether burrowing owls nest near agricultural land because of that habitat or if they historically nested there because of some other factor, e.g., soils. If the first case is true, the owl

populations are higher now than historically in southern Idaho, and if the second, populations are lower.

The striking similarity of data from this study and southwestern Idaho suggests that many pairs of owls select a specific proportion of agricultural land. If owls prefer to hunt this habitat owing to the density or availability of Microtus and thereby increase their reproductive success, this offers a great opportunity for enhancing owl populations. Extensive ecotone between range land and agriculture within the burrowing owl's range in North America may be made more suitable once other habitat requirements are met. For example, artificial nest structures may be best placed within a few hundred m of hay fields. Martin (1973) believed that this owl was "behaviorally plastic" and may be one of the raptors least affected by man-made environmental changes. It is possible that burrowing owls may be benefited by some of these changes.

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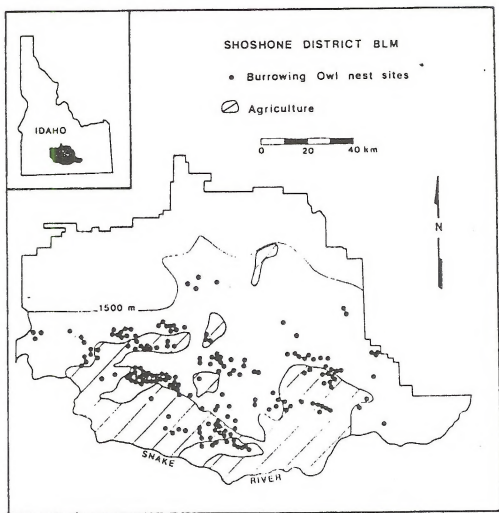


Figure 1. Location of the study area, agricultural land, and all burrowing owl nest sites located between 1976 and 1983.



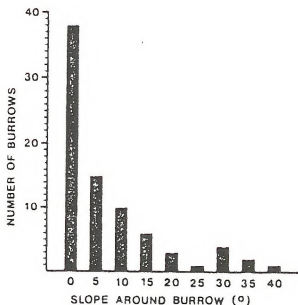


Figure 2. Location of burrowing owl burrows on different slopes.

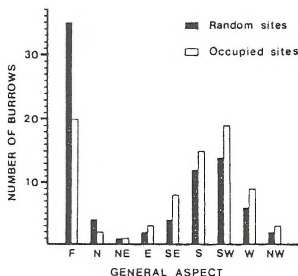


Figure 3. Number of burrowing owl burrows placed on various slope aspects determined from the general slope aspect within a 1-km radius of the burrow. Letters denote the cardinal directions and F = flat.

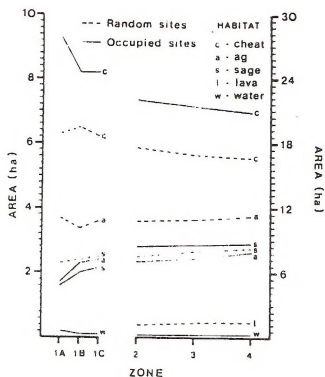


Figure 4. Area of five habitat types within six concentric zones centered on 80 occupied burrowing owl nest sites and 80 randomly chosen sites.

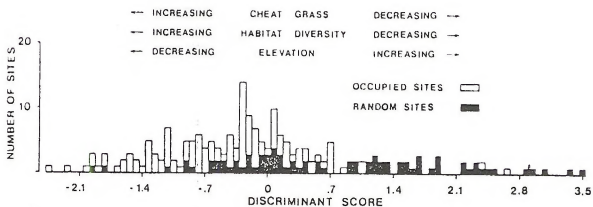


Figure 5. Discriminant scores of 127 occupied burrowing owl nest sites and 80 randomly chosen sites.

Table 1. Mean percent of cover within 50 m of 80 occupied burrowing owl nest sites and number of sites (N) with a given cover type.

Cover Type	<u>N</u>	%
Cheatgrass	77	59
Bare ground	56	19
Rock	47	7
Sagebrush	35	7
Tumble mustard	30	9
Rabbitbrush	28	4
Crested wheatgrass	21	13
Burr buttercup	19	21
Wild rye	16	2
Thistle	11	1
Perfoliate peppergrass	11	20

Table 2. Topographic variables for 80 occupied burrowing owl nest sites and 80 randomly chosen sites.

Variable	Occupied		Random		<u>P</u>
	Mean	SD	Mean	SD	
Elevation	1256 m	77	1303 m	113	< 0.005
Maximum	1276 m	84	1322 m	125	< 0.01
Minimum	1240 m	79	1288 m	105	< 0.002
Relief ^a	36 m	24	34 m	34	> 0.50
Slope	0.038	0.035	0.042	0.043	> 0.50
Dist. to Water ^a	872 m	1005	1191 m	1377	> 0.10

^a Logarithmic transformation used before t test.

Table 3. Cover of five different habitat types for 80 occupied burrowing owl nest sites and 80 randomly chosen sites. The significance of the difference between means for each type is shown.

Site	Habitat Type Cover (ha)				
	Cheat	Agriculture	Sage	Lava	Water
Random <u>N</u>	64	33	32	6	2
Mean	86.1	107.7	76.7	93.2	3.5
SD	59.5	42.3	56.5	43.0	0.6
Occupied <u>N</u>	80	30	48	0	14
Mean	86.5	77.1	58.1		3.9
SD	53.9	42.5	37.0		3.2
<u>P</u>	> 0.50	< 0.05	< 0.05	-	-

Table 4. Discriminant analysis of 80 occupied burrowing owl nest sites and 80 randomly chosen sites. See text for explanation of variables.

Step Number	Variable Entered	<u>F</u> to Enter	U-statistic	df
1	C1A	14.96	0.9135	1, 158
2	<u>H</u>	22.77	0.7978	2, 157
3	EL	6.57	0.7656	3, 156
4	LOGW	9.03	0.7229	4, 155
5	C1B	8.04	0.6871	5, 154

Table 5. Classification matrix resulting from stepwise discriminant analysis of 80 occupied burrowing owl nest sites and 80 randomly chosen sites. The 47 sites discovered in 1982 did not enter into formulation of the classification functions but were classified by them.

Group	% Correct	<u>Number of Cases Classified into Group</u>	
		Random	Occupied
Random	76.3	61	19
Occupied	78.8	17	63
Total	77.5	78	82
1982 Sites	40.4	28	19

Table 6. Discriminant analysis of 127 occupied burrowing owl nest sites and 80 randomly chosen sites.

Step Number	Variable Entered	<u>F</u> to Enter	U-statistic	df
1	ClA	20.97	0.9072	1, 205
2	H	29.22	0.7935	2, 204
3	EL	6.11	0.7703	3, 203
4	ClB	4.44	0.7538	4, 202
5	CRest	6.05	0.7317	5, 201

Table 7. Classification matrix resulting from stepwise discriminant analysis of 127 occupied burrowing owl nest sites and 80 randomly chosen sites.

Group	% Correct	<u>Number of Cases Classified into Group</u>	
		Random	Occupied
Random	62.5	50	30
Occupied	78.7	27	100
Total	72.5	77	130

Table 8. Spearman rank correlation coefficients between habitat variables and prey species in the pellets of burrowing owls from 52 nest sites in mid-July. The weight of prey species is also given.

Prey Species	Hectares in			Habitat Diversity
	Cheat Grass	Agriculture	Sagebrush	
<u>Microtus montanus</u> (38 g)	-0.32*	0.39**	-0.03	0.34*
<u>Peromyscus maniculatus</u> (17 g)	0.12	-0.28*	0.16	-0.14
<u>Perognathus parvus</u> (15 g)	0.64***	-0.38**	-0.41**	-0.61***
<u>Stenopelmatus fuscus</u> (2 g)	-0.44***	0.16	0.38**	0.42**
<u>Nicrophorus</u> spp. (0.8 g)	0.45***	-0.32*	-0.24	-0.51***
<u>Eleodes</u> spp. (0.6 g)	0.07	-0.18	0.08	0.02
grasshoppers (0.3 g)	0.11	0.01	-0.15	-0.05
<u>Prionus</u> spp. (0.3 g)	-0.32*	0.21	0.19	0.56***
Prey diversity	0.34*	-0.28*	-0.13	-0.28*

* $P < 0.05$, ** $P < 0.005$, *** $P < 0.001$.